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ABSTRACT

The contribution of heredity to scores on a digit span intelligence test, Jensen's Memory for Numbers, was estimated with a standard heritability formula. The test measures level I mental ability--the capacity to store and recall, but not ability to elaborate or manipulate stimuli. Subjects were 35 monozygotic (MZ) twins and 35 same-sex dizygotic (DZ) twins, ages 11-18 who were raised together. Twin intraclass correlations derived from the analysis of covariance of the test scores were .716 (MZ) and .497 (DZ). The broad heritability was .437 or .52 when corrected for unreliability. Height and weight measurements were also applied to the heritability formula, to compare results of these known traits to a little known trait--memory span; heritability values were .958 (height) and .730 (weight), which supported previous research. Analysis of abstract reasoning or level II ability, as measured by Raven's Standard Progressive Matrices Test, resulted in a heritability value of .897. This was a high value for mental test data. The MZ data showed no evidence of a first-order genotype by environment interaction. (Author/CP)

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A Note on the Heritability of Memory Span

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ABSTRACT

The heritability of performance on a digit span memory test was estimated by means of the twin method, using the correlations of teenage monozygotic and dizygotic twins. The broad heritability is estimated as h^2=.44, which when corrected for attenuation is increased to .52. The values of h^2 determined by the same method for height and weight are .96 and .73, respectively. The MZ data show no evidence of a first-order genotype x environment interaction.

Key words: memory span, heritability, MZ and DZ twins, height, weight.

A Note on the Heritability of Memory Span

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By means of the twin method, we have attempted to estimate the heritability (in the broad sense) of scores on a memory span test which has been frequently used as a marker of Level I ability in Jensen's research on the Level I-Level II theory of mental abilities (e.g., Jensen, 1973, 1974). In this formulation, Level I ability is essentially the capacity to receive or register stimuli, to store them, and to later recognize or recall the material with a high degree of fidelity. It is characterized by the lack of any need of elaboration, transformation, or manipulation of the input in order to arrive at the output, as contrasted with Level II ability, which is characterized by transformation and mental manipulation of the stimulus input prior to making the response. Digit span memory, particularly <u>forward</u> digit

span, exemplifies Level I ability (Jensen & Figueroa, 1975). To enable more reliable measurement of digit memory than is possible by means of the very brief digit span subtests of the Stanford-Binet and Wechsler intelligence tests, Jensen devised the Memory for Numbers test (Note 1), an auditory forward digit span test (administered by tape recorder) which has high reliability and broader factorial validity in the Level I-Level II system than the traditional memory span test. The Memory for Numbers test gains this advantage by means of repeated measurements and by varying procedural factors in order to reduce task-specific variance in the total scores.

Previous estimates of the heritability of digit span and short-term memory have been summarized by Pezzullo, Thorsen, and Madaus (1972). In general, the outcome of these older studies are virtually uninterpretable, due to the meager or unknown reliabilities of the memory tests, the small samples of twins used, and the theoretically inadequate methods of heritability estimation from measurements on monozygotic (MZ) and dizygotic (DZ) twins. Pezzullo et al. (1972) devised a tape recorded memory span test with a split-half reliability above .90, and administered it to 37 pairs of MZ and 28 pairs of DZ twins, of ages 10 to 15 years. (Pezzullo et al. mistakenly reported their Ns as 28 MZ pairs and 37 DZ pairs.) They unfortunately estimated the heritability by means of Holzinger's (1929) formula, which has been shown to be conceptually incorrect (Jensen, 1967,

1976), since it does not correspond theoretically to what is meant by heritability in quantitative genetics (Jensen, 1975). Moreover, Pezzullo et al. used twins ranging in age from 10 to 15 years and did not partial out the effect of age on the twin correlations. Since memory span is age dependent, the correlation between twins could therefore be significantly inflated by the common variable of age. Since the article by Pezzullo et al. does not contain the information required to obtain a proper estimate of heritability, Dr. Pezzullo has kindly provided us with the original data of their study so that we could apply the very same analysis that we used in our study, thereby permitting a direct comparison of their results with ours.

Method

Subjects

A questionnaire was sent to a number of junior and senior high schools in the Bay Area to identify all of the like-sexed twins enrolled, and requested that they volunteer as subjects in this study. A total of 35 MZ twin pairs and 35 like-sexed DZ twin pairs volunteered. Their ages range from 11 to 18 years. (MZ mean = 14 yrs. 7 mo., SD 1 yr. 6 mo.; DZ mean = 15 yrs. 5 mo., SD 1 yr. 6 mo.)

Zygosity Diagnosis. Twins were classified as MZ or DZ on the basis of the specially devised questionnaire and zygosity diagnosis procedure described by Nichols and Bilbro

(1966), which takes account of blood type and various physical characteristics. In addition, all twins were given the phenylthiocarbamide (PTC) taste test. About 40 percent of the population cannot taste PTC in the concentration used in this study, and any taste discrepancy between twins quite definitely rules out monozygosity. Errors in zygosity classification, of course, will diminish the estimated heritability.

Memory for Numbers Test

This test, which is administered by tape recorder to insure procedural uniformity, takes about 30 minutes. Series of from 4 to 9 simple random numbers (excluding zero, repetitons, and normal numerical order) are presented by a male voice at the rate of one digit per second. The sound of a "bong" indicates the start and the termination of each series. Ss are allowed 13 seconds between series to write as many of the digits as they can recall in the correct order on a specially prepared answer sheet. There is one series at each length of from 4 to 9 digits, in each of three experimental conditions: (1) Immediate recall, in which Ss write their recall immediately after the "bong" which comes 1 second after the last digit of each series; (2) Repeated series, in which Ss hear the same series repeated three times (separated by a "click") before writing the digits; and (3) Delayed recall, in which Ss must delay their recall until 10 seconds have elapsed after the last

digit in the series, the end of the 10-second interval being signalled by a "bong." To insure that all Ss understand the instructions and procedure, each experimental procedure is preceded by a short practice test (which is not scored) consisting of three different digit series each of three digits. In each case the procedure for the practice test is identical to the particular experimental condition that follows it. The S's score on the Memory for Numbers test is the total number of digits recalled in the correct position, with a maximum possible score of 117.

All Ss were tested by Dr. Marisi as part of a larger study (Note 2).

Heritability Estimation

We have estimated heritability in the broad sense by using the simplest heritability formula, which is commonly used in quantitative genetics (e.g., Falconer, 1960). It is $h^2=2(r_{MZ}-r_{DZ})$, where h^2 is the estimated broad heritability, and r_{MZ} and r_{DZ} are the intraclass correlations for MZ and DZ twins. The rationale, assumptions, and limitations of this method of estimating heritability have been explicated in detail elsewhere (Jensen, 1976). It is a conservative estimate of heritability in that it assumes random mating for the trait in question, so the formula underestimates the broad heritability when there is in fact assortative mating for the trait. However, since we have no precise information on assortative mating for memory span, it seems

preferable to assume random mating and obtain a lower-bound estimate of the broad heritability. If there is dominance deviation for the trait, the above formula will slightly overestimate the broad heritability. We have no knowledge of dominance deviation for memory span. Thus, the broad heritability will be somewhat underestimated by the above formula to the extent that there is assortative mating, and it will be slightly overestimated to the extent that there is dominance. The two biases, if both exist, tend to cancel each other to some extent.

The standard error of h^2 is estimated by the formula given by Loehlin, Lindzey, and Spuhler (1975, p.288):

$$SE_{h^2} = 2\left(\frac{(1-r_{MZ}^2)^2}{N_{MZ}} + \frac{(1-r_{DZ}^2)^2}{N_{DZ}}\right)^{1/2} .$$

Since the raw memory span scores are age dependent, it is essential statistically to control the effect of age in calculating the intraclass correlation between twins. This can be done by analysis of covariance, in which the total variance can be partitioned into four components associated with: (1) the regression of differences between twin pairs on age, (2) the regression of differences within twin pairs on age, (3) the residual differences between pairs, and (4) the residual differences within pairs. The twin intraclass correlation (r_i) can be calculated from the mean squares (MS) associated with (3) and (4), as follows:

$r_i=(MS_3-MS_4)/(MS_3+MS_4)$. The correlation is significantly greater than zero if $(MS_3/MS_4)=F$ is significant for the given degrees of freedom. The r_i thus obtained for a sample of twin pairs of differing ages approximates the expected value of r_i for a sample of twin pairs all of the same age. In no case, with the present sample sizes, did a nonlinear (quadratic) component of the regression of between pairs and within pairs effects on age even approach statistical significance; so only the linear regression of effects on age are partitioned in the analysis of covariance, from which the twin intraclass correlations are derived, as described above.

When a particular method of heritability analysis is applied for the first time to a variable about the genetics of which little or nothing is known, it seems wise to apply exactly the same analysis to physical variables measured in the same twin samples about which we already have considerable knowledge as to the heritability. Heritability estimates of the physical measurements, as R.A Fisher was the first to suggest, can serve as a "sheet anchor" for comparison of the results of applying the same method of analysis to a little known trait -- in the present case, memory span. Therefore, we have secured height and weight measurements (which, like memory span, are age dependent) on all the twins, and have applied exactly parallel analyses to these physical measurements.

Results and Discussion

Memory for Numbers Test

The results of the analysis of covariance of the Memory for Numbers scores are shown in Table 1. The twin

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Insert Table 1 about here

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intraclass correlations derived therefrom are r_{MZ}=.716 and r_{DZ}=.497. A conventional test of the significance of a genetic effect is $F=MS_{WDZ}/MS_{WMZ}$, i.e., the ratio of the within pairs variance for DZ and MZ twins. In this case, F=2.65, which with 33 and 34 *df* is significant beyond the .01 level. The h^2 is .437, *SE*=.303 (t=1.44, one-tailed $p<.10$).

Since we can determine the internal consistency reliability of the test scores, using the Hoyt (1941) method, we can correct the obtained h^2 for attenuation (unreliability). The reliability of the memory scores is .84. The corrected h^2 is .437/.84=.52.

If there were the same degree of assortative mating for memory span as for IQ, i.e., a correlation of about +.45 between parents (Jensen, 1978), the attenuation corrected estimate of h^2 would be increased to at least .60.

Comparison with Pezzullo et al.

We can compare the above results with those obtained from a parallel analysis of the twin data on a test of memory span used in the study by Pezzullo et al. (1972), shown in Table 2. The twin correlations are r_{MZ}=.764

Insert Table 2 about here
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and r_{DZ}=.414. The ratio of within pairs variance for DZ and MZ twins is F=2.37, p<.02. The h^2=.700, SE=.342 (t=2.05, one-tailed p<.03).

Raven's Progressive Matrices

Pezzullo et al. administered Raven's Standard Progressive Matrices Test, a highly g loaded test of abstract reasoning or Level II ability, to the same twin samples. Since they failed to take account of age in their analysis, we have re-analyzed their Raven Matrices data by the same method that was applied to the memory scores, with the results shown in Table 3.

Insert Table 3 about here

The twin correlations are r_{MZ}=.817 and r_{DZ}=.369. The F ratio for the DZ/MZ within-pair variances is 5.91, p<.01. The h^2=.897, SE=.344 (t=2.60, one-tailed p<.01). This is surely one of the highest heritabilities for a mental test

ever reported in the literature.

Height and Weight

Table 4 shows the same analysis applied to the height and weight measurements obtained in the present twin samples.

For height the twin correlations are r_{MZ}=.973

Insert Table 4 about here
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and r_{DZ}=.494. The F ratio for the DZ/MZ within-pair variance is 32.39, $p<.01$. The h^2=.958, SE=.256 (t=3.74, one-tailed $p<.01$).

For weight the twin correlations are r_{MZ}=.976 and r_{DZ}=.611. The F ratio for the DZ/MZ within-pair variances is 22.96, $p<.01$. The h^2=.730, SE=.212 (t=3.44, one-tailed $p<.01$).

Thus the broad heritabilities of height and weight, as estimated by the present method, are quite in accord with expectations (cf., Fisher, 1918; Bulmer, 1970).

Genotype x Environment Interaction

Jinks and Fulker (1970) have proposed a method, based on MZ twins, for determining one kind of genotype x environment interaction, that is, the extent to which environmental effects depend upon genotypes. The method detects only

first-order interaction, that is, interaction which arises from linear regression of environmental effects on genotypic values. The method is more ideally applied to MZ twins who are reared apart in uncorrelated environments. When applied to MZ twins who are reared together, as in the present twin data, the method detects only the linear regression of within-family microenvironmental effects on the composite of genotype plus between-families environmental effects. Specifically, the method consists of computing the correlation r_{ab} between two sets of variables: (a) the sum of the scores for each pair of MZ twins, and (b) the absolute difference in scores for each pair of MZ twins. This correlation (with the effect of age partialled out) was obtained for each of the sets of MZ twins shown in Tables 1-4. None of the correlations is larger than its standard error, except for the Pezzullo et al. memory scores, for which the correlation (with age partialled out) between MZ sums and differences is -.35, $p<.05$.

Reference Notes

1. Jensen, A.R., & Rohwer, W.D., Jr. An Experimental Analysis of Learning Abilities in Culturally Disadvantaged Children. Final Report, Office of Economic Opportunity. Contract No. OEO2404, 1970.

2. Marisi, D.Q. The genetic component in motor performance and numeric memory. Unpublished doctoral dissertation, Univerity of California, Berkeley, 1972.

References

Bulmer, M.G. The Biology of Twinning in Man. Oxford: Clarendon Press, 1970.

Falconer, D.S. An Introduction to Quantitative Genetics. New York: Ronald Press, 1960.

Fisher, R.A. The correlation between relatives on the supposition of Mendelian inheritance. Transactions of the Royal Society, Edinburgh, 1918, 52, 399-433.

Holzinger, K.J. The relative effect of nature and nurture influences on twin differences. Journal of Educational Psychology, 1929, 20, 241-248.

Hoyt, C.J. Note on a simplified method of computing test reliability. Educational and Psychological Measurement, 1941, 1, 93-95.

Jensen, A.R. Estimation of the limits of heritability of traits by comparison of monozygotic and dizygotic twins. Proceedings of the National Academy of Science, 1967, 58, 149-157.

Jensen, A.R. Level I and Level II abilities in three ethnic groups. American Educational Research Journal, 1973, 10, 263-276.

Jensen, A.R. Interaction of Level I and Level II abilities with race and socioeconomic status. Journal of Educational Psychology, 1974, 66, 99-111.

Jensen, A.R. The meaning of heritability in the behavioral science. Educational Psychologist, 1975, 11, 171-183.

Jensen, A.R. The problem of genotype-environment correlation in the estimation of heritability from monozygotic and dizygotic twins. Acta Geneticae Medicae et Gemellologiae, 1976, 25, 86-99.

Jensen, A.R. Genetic and behavioral effects of nonrandom mating. In R.T Osborne, C.E. Nobel, & N. Weyl (Eds.) Human Variation: Psychology of Age, Race, and Sex. New York: Academic Press, 1978.

Jinks, J.L., & Fulker, D.W. Comparison of the biometrical genetical, MAVA, and classical appracches to the analysis of human behavior. Psychological Bulletin, 1970, 73, 311-349.

Loehlin, J.C., Lindzey, G., & Spuhler, J.N. Race Differences in Intelligence. San Francisco: Freeman, 1975.

Nichols, R.C., & Bilbro, W.C. The diagnosis of twin zygosity. Acta Genetica, 1966, 16, 327-352.

Pezzullo, T.R., Thorsen, & E.E., Madaus, G.F. The heritability of Jensen's Level I and II and divergent thinking. American Educational Research Journal, 1972, 9, 539-546.

Table 1

Analysis of Covariance of Memory for Numbers Test

		MZ Twins		DZ Twins	
Source of Variance	df	MS	F	MS	F
Between Pairs (Residual)	33	231.94	6.04**	303.78	2.98**
Within Pairs (Residual)	34	38.40		101.99	
Regression on Age (Between)	1	13.33	<1	274.65	2.69
Regression on Age (Within)	1	337.86	8.80**	244.41	2.40

** $p<.01$

Table 2

Analysis of Covariance of Memory Span Scores

from Study by Pezzullo et al. (1972)

	MZ Twins			DZ Twins		
Source of Variance	df	MS	F	df	MS	F
Between Pairs (Residual)	35	1451.63	7.47**	26	1110.65	2.41*
Within Pairs (Residual)	36	194.43		27	460.58	
Regression on Age (Between)	1	26835.14	138.02**	1	5904.86	12.82**
Regression on Age (Within)	1	818.68	4.21*	1	22.43	<1

* $p<.05$

** $p<.01$

Table 3

Analysis of Covariance of Raven's Progressive Matrices Scores from Study by Pezzullo et al. (1972)

	MZ Twins			DZ Twins		
Source of Variance	df	MS	F	df	MS	F
Between Pairs (Residual)	35	71.55	9.92**	26	92.29	2.17*
Within Pairs (Residual)	36	7.21		27	42.58	
Regression on Age (Between)	1	916.48	127.11**	1	1520.51	35.71**
Regression on Age (Within)	1	0.57	<1	1	199.93	4.69*

* $p<.05$

** $p<.01$

Table 4

Analysis of Covariance for Height and Weight

		Height (Inches)				Weight (Pounds)			
		MZ Twins		DZ Twins		MZ Twins		DZ Twins	
Source of Variation	df	MS	F	MS	F	MS	F	MS	F
Between Pairs (Residual)	33	20.65	73.75**	26.61	2.95**	678.51	83.46**	773.67	4.14**
Within Pairs (Residual)	34	0.28		9.07		8.13		186.68	
Reg.on Age (between)	1	136.50	487.50**	802.05	88.43**	18720.10	2303.59**	18190.41	
Reg.on Age (within)	1	1.46	5.21*	6.73	<1	64.44	7.93**	1087.46	

*$p<.05$

**$p<.01$